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HEART RATE AND STIMULUS GENERALIZATION IN A PAIRED ASSOCIATES TASK

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Heart Rate and Stimulus Generalization in a Paired Associates Task" submitted by Richard Wallace Nutter in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

Two experiments were conducted to study the relationship(s) between stimulus generalization in a paired associates (PA) task and heart rate (HR) and galvanic skin response level (GSR). Similarity ratings of twelve low-meaningful CVC trigrams were collected from 85 Ss in Experiment 1. These CVCs were used as stimulus elements paired with common three letter nouns as responses in the PA task of Experiment 2. Behavioral data collected from 20 Ss provided strong evidence supporting the presence and appropriate measurement of stimulus generalization in Experiment 2. HR and GSR were recorded continuously during Experiment 2. There was no consistent evidence relating HR or GSR to stimulus generalization. GSR was significantly related to learning performance such that the higher the GSR level the poorer the learning performance in Experiment 2.

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INTRODUCTION

This study was initially undertaken to ascertain the generality of findings reported by Callaway and Thompson (1953), Lacey (1959), Lacey, Kagan, Lacey and Moss (1963) and Obrist (1963). Their findings suggested links between heart rate (HR) and perceptually based overt behavior. Relatively low HR seems to accompany accurate utilization of exteroceptive stimuli and relatively high HR, internal ideation.

Callaway and Thompson (1953) found that "given adequate cues as to distance, the majority of a group of subjects ... will when matching the size of an object at about 200 cm. to an object within arm's length tend to make the far object relatively larger while one foot is immersed in ice water or following the inhalation of amyl nitrite" (p. 451). These two treatments reliably lead to an increase in HR. This could be interpreted as evidence for poor utilization of distance cues during periods of relatively high HR resulting in low size constancy.

Lacey (1959) reported that when _S_s were asked to respond only when the center light of a three light panel flashed, HR comcomitant with correct responses was found to be lower than HR concomitant with errors. In the same situation, the lights were automatically flashed when HR was spontaneously high or low. The _S_s made more errors to lights flashed when their HRs were relatively high than

when their HRs were relatively low (Lacey, 1959).

Lacey _et al._, (1963) presented evidence indicating that tasks requiring attention to external stimuli such as looking at color slides, listening to an auditory passage, listening to white noise, and looking for hidden faces in a drawing are accompanied by HR decreases. They report that HR increases during the immersion of a foot in ice water and during the performance of a mental arithmetic task (multiplication of a two-digit number by a one-digit number then adding a two-digit number to the resultant product). Obrist (1963) replicated most of the findings of Lacey _et al._, (1963).

Steele and Koons (1968) and Steele and Lewis (1968) found HR increases during mental arithmetic in confirmation of Lacey _et al._, (1963) and Obrist (1963). Steele and Koons (1968) found that white noise during the mental arithmetic task increased HR still further whereas Obrist (1963) and Lacey _et al._, (1963) found that white noise alone decreased HR.

Studies by Campos and Johnson (1966) and Johnson and Campos (1967) indicate that instructions regarding verbalizations produce significant effects on HR and skin conductance level (SCL).[1] When _S_s were instructed to remain silent and imagine common scenes or look at complex stimuli, no significant effects on HR or SCL

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[1] See Appendix A for a brief discussion of the psychophysiological variables discussed in this paper.

were observed. However, when Ss were instructed to verbalize after or concurrently with these tasks, HR and SCL increased. The mental arithmetic task used by these investigators increased HR and SCL. The HR and SCL increases during mental arithmetic were greater under instructions to verbalize.

Docter, Kaswan, and Nakamura (1964) failed to replicate Lacey's (1959) findings concerning HR and responding to flashing lights. They used an apparatus with eleven lights, all separated from the center light by multiples of 4° of visual angle to the left or right of center. They conclude that Lacey's findings might have been due to some particular aspect of his experimental situation which they were unable to replicate.

Since the situation used by Lacey (1959) and Docter et al., (1964) was a reaction time (RT) type of situation, one might expect a relationship between HR and RT. Docter et al., (1964) and Meyers (1966) failed to find a relationship between HR and RT. Elliot (1964) found a relationship between HR and SCL and RT that depended upon the level of incentive in adults. However, in kindergarten children, only HR was related to RT depending upon incentive level. That is, HR increased and RT decreased as incentive increased for both adults and children but SCL increased over incentive conditions only in adults.

The finding of Steele and Koons (1968) that mental arithmetic performed during a white noise distraction was accompanied by even higher HRs than mental arithmetic performed during quiet, considered

with the findings of Lacey _et_ _al_., (1963) and Obrist (1963) that white noise alone decreases HR, implies that HR acceleration might be correlated with rejection of exteroceptive stimuli (distractions). Other findings of Lacey _et_ _al_., (1963), replicated by Obrist (1963), suggest that tasks requiring careful noting of or close attention to exteroceptive stimuli are accompanied by HR deceleration. Studies of the orienting response as reviewed by Graham and Clifton (1966) also suggest that shifts of attention to exteroceptive stimuli are accompanied by HR deceleration.

Psychophysiological variables other than HR have been studied in some of the investigations cited above. Lacey _et_ _al_., (1963) report that SCL increased to all tasks even though, as mentioned above, HR increased or decreased selectively depending on the stimulus intake-rejection requirements of the task. Obrist (1963) found that skin resistance level (SRL) decreased to all tasks except the viewing of color slides whereas HR reacted selectively. Campos and Johnson (1966), Johnson and Campos (1967) and Elliot (1964) found that HR and SCL both increased with the exception noted above in Elliot's study.

Lazarus and his coworkers (Lazarus, Speisman & Mordkoff, 1963; Malmstrom, Opton & Lazarus, 1965; Lazarus, Tomita, Opton & Kodama, 1966; and Nomikos, Opton, Averill & Lazarus, 1968) seem to assume a simple unitary arousal hypothesis. Such an hypothesis holds that different psychophysiological measures are virtually interchangeable operationalizations of arousal. The plausibility of such an hypothesis

depends upon the magnitude and consistency of the relationships between different psychophysiological measures collected in the same situations. Lazarus and his coworkers have been unsuccessful in their attempts to demonstrate very high correlations between HR and GSR. The results obtained by Lacey et al., (1963) and Obrist (1963) argue against a simple unitary arousal explanation of the findings relating HR to inward versus outward directed attention. The conflicting findings relating HR and GSR to environmental and behavioral phenomena suggest that the collection of multiple psychophysiological measures may provide an empirical basis for the development of more elegant theory relating psychophysiological phenomena to behavioral phenomena.

Lacey (1967) comes to the conclusion that HR increases are concomitant with stimulus rejection and internal ideation and that HR decreases are concomitant with attending to and accurate noting of exteroceptive stimuli. Most of the demonstrations of HR deceleration concomitant with tasks requiring attention to exteroceptive stimuli have employed simple non-noxious, nonsignal stimuli requiring no specific response from the S. The notable exceptions to this are the tasks with flashing lights used by Lacey (1959) and modified by Docter et al., (1964) in an experiment which failed to replicate Lacey's findings. Thus, Lacey's (1967) conclusion that HR and the processing of environmental stimuli are reliably related is based upon evidence obtained in relatively simple situations. The theoretical and practical importance of Lacey's conclusion would be

greatly enhanced by a demonstration of the relationship between HR and stimulus processing in a more complex behavioral situation. Responding in tasks requiring both accurate intake and processing of environmental stimuli and internal ideation should be reliably related to relative HR. Responses emitted when relative HR is low should reflect accurate processing of exteroceptive stimuli whereas responses emitted when HR is relatively high should reflect less accurate processing of exteroceptive stimuli. A paired associates (PA) task, constructed so as to permit analysis of response data in terms of stimulus generalization, is appropriate for examining the relationship between stimulus utilization and relative HR.

Stimulus generalization, as used here, is a term descriptive of an empirical phenomenon. This is similar to the usage implied by Brown's first description of stimulus generalization as "a simple, concrete empirical phenomenon" (1965, p. 7). Kimble (1961), Mostofsky (1965) and Terrace (1966) cite enough examples of stimulus generalization to justify strictly empirical usage of the term. As an empirical phenomenon it is often displayed graphically on a two coordinate system, the abscissa of which represents some independent scaling of the stimuli of interest (stimulus elements of the PA list in this case) and the ordinate some scaling of response strength (frequencies of particular intralist response interchanges in this case) to particular stimulus presentations. The response strength typically varies with abscissa scale position such that it is strongest to the critical stimulus and progressively

[illegible]

weaker to stimuli progressively further from the critical stimulus on the abscissa scale.

The critical characteristic of stimulus generalization, as defined here, is that there be a substantial relationship between the abscissa scaled characteristic(s) of the stimuli and the recorded response strengths. The observed relative response strengths should vary over the width of the abscissa scale and be predictable from the abscissa scale position.

It was expected that similarity judgements (Runquist and Joinson, 1968) of low-meaningful (Archer, 1960) CVC trigrams would provide an appropriate abscissa scale when the similarity scaled CVCs were used as the stimulus elements of a PA list. A high positive correlation between the similarity of stimulus elements and the frequency of response interchanges between stimulus elements constitutes evidence for stimulus generalization, as defined above, in a PA task. The correlation between HR and individual response interchanges (generalization responses) in a PA task will provide information concerning the relationship between stimulus utilization and momentary HR levels. This assumes that interchanges between dissimilar stimuli reflect less accurate stimulus utilization than response interchanges between similar stimuli thus the former should be accompanied by higher HR than the latter.

Suppose that the learning phase of a PA task places relatively more emphasis upon stimulus intake than the testing phase which places more emphasis upon internal ideation (recalling). If this is true

and the relationship between relative HR and inward versus outward directedness of attention suggested by the literature reviewed above is true, then HR should be lower during the learning than during the testing phase of a PA task.

Hokanson and his coworkers (Hokanson and Burgess, 1964; Burgess and Hokanson, 1964; and Doerr and Hokanson, 1965) used HR as an operational measure of Drive. They selected subjects with high HRs as being high in Drive and those with low HRs as being low in Drive. They found HR to be positively related to performance on a digit symbol substitution task. Berry and Davis (1960) did not find significant relationships between HR and GSR and performance on a rote learning task using _S_s _not_ selected for their mean HR levels. The data collected in the present study were analyzed to determine the relationships between HR and GSR and learning performance in this PA task.

Two experiments were conducted in keeping with the general _a priori_ methodological considerations detailed in Appendix G. The resultant data were utilized to obtain answers to the following three questions:

1. Does HR correlate with stimulus generalization?

2. In a relatively complex behavioral situation, is HR concomitant with tasks placing relatively more emphasis upon accurate intake of environmental stimuli relatively lower than HR concomitant with tasks placing relatively more emphasis upon internal ideation?

3. Do HR and GSR levels of _S_s relate to their learning performance in a PA task?

Experiment 1 was a partial replication and expansion of Runquist and Joinson (1968). It was conducted to produce a similarity scale of stimulus elements used in Experiment 2. Experiment 2 was a PA task constructed so as to permit analysis of response data in terms of stimulus generalization. HR and GSR data were collected continuously during Experiment 2.

EXPERIMENT 1

METHOD

Subjects

Ss were 85 volunteers, 45 of whom were introductory psychology students, 10 secretaries and 30 students enrolled in an abnormal psychology course offered in the Summer session at the University of Alberta. Data from five of the 85 Ss were not used because they were either incomplete or utilized less than one third of the 100 point rating scale.

Materials

Twelve low-meaningful CVC trigrams (Archer, 1960) were presented in pairs, with each of the 66 possible pairs being presented to each S in both orders (e.g., XIL-YIL and YIL-XIL). The pairs were printed in a non-systematic order in a small 12 page booklet, the first page of which contained the instructions used by Runquist and Joinson (1968). Appendix B contains a copy of the booklet.

Procedure

The instructions were read to the Ss and they were allowed to rate the pairs of CVC trigrams taking as much time as they needed. Ss were instructed to rate the similarity from 0 (no similarity) to 100 (identity). Ss returned the booklets to the E when they had completed the similarity ratings.

RESULTS

Means and standard deviations were computed for each pair of CVCs by order and with orders pooled. The standard deviations of the 66 pairs with two orders ranged from 14.3 to 26.7 and for the 66 CVC pairs with orders pooled from 15.1 to 23.7. The largest difference between the mean rating of a CVC pair in one order and the other order of presentation was 8.41. The mean difference in mean ratings of CVCs by order was not significant ($t = .6470$ with 65 df). The Pearson product moment correlation coefficient between the Ss' mean similarity ratings of the CVC pairs' first order and second order of presentation was $r = .99$, indicating that the order of presentation had relatively little effect on the rank order of rated similarity. Table 1 presents the mean rated similarity of all the CVC pairs for the first order of appearance in the booklet, second order of appearance and orders pooled. These results are substantially in agreement with those obtained by Runquist and Joinson (1968). The notable exception is that the mean similarity ratings shown here for CVCs sharing no letters are somewhat higher than those obtained by Runquist and Joinson (1968).

TABLE 1

MEAN SIMILARITY RATINGS OF CVC TRIGRAMS

CVC pair	Position* in booklet	First Order	Second Order	Orders Pooled
XIL - FAJ	43	10.22	11.29	10.755
QIH - MUB	3	10.84	11.67	11.255
MUB - YIH	12	11.00	11.67	11.335
QOH - MUB	50	10.39	12.43	11.41
QOH - XIL	37	10.71	12.13	11.42
QIH - VAW	23	11.92	11.42	11.68
WUX - QIH	114	11.65	11.95	11.80
XIY - MUB	57	11.19	12.54	11.865
FAJ - QOH	29	12.05	11.70	11.875
FAJ - MUB	68	12.41	11.43	11.92
QOH - XIY	4	14.35	9.7	12.025
PEF - XIL	73	12.66	11.66	12.16
YIL - QOH	123	12.42	12.	12.21
PEF - NIY	24	13.04	11.67	12.355
MUB - XIL	91	12.17	12.58	12.375
XIY - PEF	76	11.27	13.76	12.515
YIL - PEF	54	12.24	12.81	12.525
QIH - FAJ	9	13.1	12.31	12.705
FAJ - XIY	5	13.75	11.76	12.755
PEF - WUX	61	11.78	13.81	12.795
YIL - MUB	30	13.06	12.68	12.87
VAW - PEF	52	12.25	13.63	12.94
PEF - QOH	42	11.56	14.34	12.95
FAJ - WUX	21	11.72	14.37	13.045
NIY - MUB	40	13.13	13.08	13.105
PEF - MUB	8	13.97	12.28	13.125
PEF - YIH	1	15.38	10.94	13.16
QOH - WUX	84	13.44	13.04	13.24
FAJ - YIH	70	14.17	12.67	13.42
YIL - FAJ	28	12.94	14.13	13.535
MUB - VAW	15	15.66	11.57	13.615
QOH - NIY	33	14.81	12.56	13.685
WUX - YIH	72	13.44	14.37	13.905
VAW - QOH	48	14.24	13.81	14.025
FAJ - NIY	10	15.96	12.15	14.055
VAW - NIY	36	13.31	15.42	14.37
QIH - PEF	13	16.61	12.15	14.38
YIL - WUX	41	13.3	15.61	14.455
VAW - XIY	56	14.18	14.8	14.49
VAW - XIL	93	15.53	14.25	14.89

TABLE 1 (con't.)

CVC pair	Position* in booklet	First Order	Second Order	Orders Pooled
YIL - VAW	98	15.71	14.09	14.9
NIY - WUX	2	13.97	16.2	15.085
YIH - VAW	11	18.39	17.66	18.025
FAJ - PEF	75	17.19	21.78	19.485
XIL - WUX	45	24.53	22.49	23.51
QOH - YIH	20	25.24	24.37	24.805
WUX - XIY	7	27.77	23.86	25.815
VAW - FAJ	89	26.16	27.48	26.82
WUX - VAW	31	30.47	29.42	29.945
QIH - YIL	35	32.73	30.08	31.405
QIH - XIY	102	29.81	33.14	31.475
XIL - QIH	18	32.46	32.63	32.545
NIY - QIH	14	34.38	31.57	32.975
MUB - WUX	6	34.68	33.56	34.12
XIL - NIY	16	34.85	38.89	36.87
YIH - XIL	116	40.59	48.	44.295
XIL - NIY	38	49.72	49.73	49.725
YIH - NIY	83	49.75	52.23	50.99
XIL - XIY	53	51.52	51.42	51.47
XIY - YIH	100	52.57	52.86	52.715
QIH - QOH	115	56.09	63.08	59.585
YIH - QIH	60	55.51	63.92	59.715
XIL - XIY	22	64.56	65.62	65.09
XIY - NIY	63	64.96	65.8	65.38
YIL - YIH	44	69.77	64.82	67.295
XIL - YIL	25	70.23	72.76	71.495

*These are the positions in the booklet in which each CVC pair first appeared. The CVCs are shown above in the order in which they first appeared. Their second appearance was in the reverse order.

EXPERIMENT 2

METHOD

Subjects

Subjects were 11 female and 11 male volunteers between the ages of 19 and 30 years who received $4.00 each for participating in the experiment. In the case of one female and one male S the experiment had to be interrupted and the subjects dropped from the experiment due to equipment malfunction. Their data are not reported.

Paired Associates Material

An eight pair list of practice material was made up using "geometrical" figures as stimuli (SEs) and single arabic numerals as responses (LRs). Appendix C contains this practice list. Three different non-systematic[2] orders of these SE-LR pairs and of the SEs (geometric shapes) alone were photographed on 16 mm. film with one order of SE-LR pairs followed by a blank frame followed by an order of SEs alone followed by a blank frame, etc.

The twelve CVC trigrams (SEs) used in Experiment 1 were paired with twelve common three letter nouns (LRs) selected from the two highest frequency categories of the Thorndike-Lorge wordbook (1944). Care was taken to select nouns with as little formal or meaningful similarity to one another as possible.

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[2]The non-systematic orders used were taken from a table of random numbers but were adjusted where necessary to prevent more than one order from beginning with the same SE or pair.

Four different non-systematic orders of SE-LR pairs (orders of learning events) and four different non-systematic orders of the SEs alone (orders of test events) were photographed on 16 mm. film with blank frames between each learning and each test order. Positive prints of the film were spliced into loops so that the Ss were presented with an order of twelve SE-LR pairs (learning events) followed by a blank frame (blank event) followed by an order of the SEs alone (test events) followed by a blank frame (BE), etc., until all four orders of learning events (LEs) and test events (TEs) had appeared at which time they began to be repeated. Appendix D contains the orders of LEs and TEs for the PA task.

Apparatus

A Dunning Animatic 16 mm. film-strip projector was used to backproject the practice and experimental material onto a 3 x 5 in. opaque screen placed slightly above eye level and approximately 30 in. in front of the S. Ss were seated in a wooden chair equipped with an adjustable padded headrest. A Hunter 111c Silent Decade Timer wired to recycle was used to time presentations at 3 sec. per frame of film.

HR was recorded continuously using a Grass Instruments Model 5DWC1 Polygraph with input from the S via a Grass Instruments PTTN Photoelectric Transducer attached to the S's ear. A Grass Instruments Model 5P4D EKG and Tachograph Pre-amplifier was used to modify the signal from the photoelectric transducer such that the

amplitude of the ink record on the paper travelling at 3 mm. per sec. was directly proportional to the time between heart beats. Padded earphones were placed on the Ss head to limit the movement of the photoelectric transducer relative to the S's ear and thus avoid artifacts.

A Grass Instruments Model 5P1 Low Level D.C. Pre-Amplifier adjusted to an effective sensitivity of 1 k ohm resistance change per 1 mm. pen deflection was used for recording SRL continuously on another channel of the Grass Instruments Model 5DWC1 Polygraph. Zinc electrodes with zinc-sulfate paste made in accordance with the instructions given by Lykken (1959) were used for GSR. The inactive electrode was placed over an abrasion made with fine sandpaper on the inside of the S's left arm. The active electrode was placed over the center of the left thumb print using a Dr. Scholl's No. K11 corn pad to limit the size of the electrolyte contact area. The marker pen on the polygraph was wired into the projector timing circuit such that the presentation of each film frame (TE, BE, or LE) was clearly marked on the polygraph record.

Procedure

The S entered the experimental room and was seated facing a table upon which electrodes, electrolyte, corn-plasters, adhesive tape, and sandpaper were lying. The E carefully inspected the S's left thumb as he explained to the S that the "measuring devices" he was about to attach would aid in collecting data on the S's

internal reactions. The left thumbs of all Ss were free of cuts and abrasions thus it was unnecessary to attach the electrode to the right thumb of any S. The E then sanded a small area of skin on the inside of the S's left arm instructing the S to tell the E as soon as the sanding started to sting. The E carefully explained that he wanted to remove only the outside layer of skin. The E stopped sanding as soon as he could see blood starting to seep through the capillaries. This method was found to reliably produce the low resistances needed for the inactive electrode placement. A corn plaster, electrolyte and electrode were placed over the small abrasion and taped in place. The S was assured that the worst part of the experiment would be the removal of the tape. Adhesive tape was then pressed on to and removed from the S's left thumb print several times to remove excessive skin oils and sweat before the cornplaster, electrolyte, and electrode were attached. The S was instructed not to press against the measurement device attached to his thumb so as to avoid the creation of artifacts.

The S was then seated in the wooden chair facing the screen and the E adjusted the headrest as the S directed for maximum comfort. The E then showed the photoelectric transducer to the S and told him it would measure his heart beat. After the E completed attaching the photoelectric transducer to the S's ear lobe and placing the earphones on the S, he instructed the S to relax and adjusted the polygraph. The GSR recording pen was centered and

the cardiotachometer was adjusted so that it triggered once and only once to every heart beat.

The E then enquired as to the S's comfort and readjusted the headrest if asked to do so. The instructions contained in Appendix E were then read to the S and the practice material was presented for six learning and six testing trials. Any final polygraph adjustments necessary were made at this time. The E recorded the S's responses and urged the S to respond to every test event (TE) in case he hesitated to do so.

After the practice material the E asked the S if he was comfortable and readjusted the headrest if asked to do so. The E then read the remainder of the instructions (reproduced in Appendix E) to the S and changed films in the filmstrip projector. If the S failed to respond to a TE the E said, "respond every time".

The E recorded the S's response to every TE on a score sheet like that in Appendix F. The paired associates task continued for 20 trials. Thus the film recycled five times and each order of LEs and TEs appeared five times.

After the PA task was completed the earphones, photoelectric transducer and electrodes were removed. The purpose of the experiment was explained to the S and the S was paid and thanked.

RESULTS

The overt behavioral results will be presented followed by the heart rate inter-beat interval (HRibi), heart rate beats per minute (HRbpm), skin resistance level (SRL), and skin conductance level (SCL) results.

Learning and Generalization Data

There were no differences between male and female Ss in number of correct responses (CRs) on either practice or main experimental lists ($t < 1$) so data from all Ss were pooled.

The total intra-list similarity of each stimulus CVC (SE1) to all of the other stimulus CVCs (SE_os) in the list was computed by summing the mean similarity rating between each SE1 and every other SE on the list. Table 2 presents these data along with the number of CRs to each SE1 summed over Ss. The Pearson product-moment correlation coefficient between total intra-list similarity of each SE1 and the number of CRs to that SE1 is -.86 ($p < .005$). Thus total intra-list similarity accounts for approximately 75% of the variance in number of CRs to SEs.

Mean rated similarity was selected as the abscissa scale for generalization. The generalization value (GV) of response interchanges (LR_o) to a SE1 was taken to be the mean rated similarity of the SE1 to the SE_o to which the LR_o would have been the correct response (CR). For example, CAR was the CR to YIH and DOG the CR to XIY. When DOG was the LR_o given to SE1 YIH, or when CAR was the LR_o given to SE1 XIY, the generalization value of the response (GVR of

TABLE 2

SE TOTAL INTRA-LIST SIMILARITY AND TOTAL NUMBER OF CRs

SE	Total Intra-list Similarity	Total No. of CRs
YIH	369.69	205
XIY	355.60	223
YIL	351.90	228
XIL	335.41	272
NIY	318.59	278
QIH	309.50	311
WUX	207.72	306
QOH	197.22	346
VAW	185.97	334
FAJ	160.35	292
MUB	157.00	347
PEF	148.40	372

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

the LR_o) was taken to be 52.72 since that was the mean rated similarity between YIH and XIY. The correlation coefficient between the GVR and the frequency of the LR_os of that GV was .84 ($p < .005$ with 64 df). This high correlation which accounts for slightly more than 70% of the variance indicates generalization gradients about the SEls of the usual skewed or peaked variety. Note that these data do[illegible] not include data from test events where Ss gave no response (NoR) or responses not on the PA task list (NLR). NoRs and NLRs summed across Ss were 63 and 128 responses respectively. Together they make up only 3.98 of the Ss' responses and 17.86% of the Ss incorrect responses. There were no significant correlations between these response categories and the total intra-list similarity, number of CRs given to, or number of LR_os given to the SEl to which NoRs or NLRs were given.

An examination of the learning and generalization data pooled over SEs instead of over Ss yielded the following results.

1) As would be expected, the number of CRs given by a S was highly and negatively correlated with the number of LR_os given by that S, $r = -.94$ ($p < .005$ with 18 df).

2) The number of CRs given by a S was correlated -.63 ($p < .005$ with 18 df) with the sum of the NoRs and NDRs given by a S.

3) Mean generalization value of LR_os (MGVR) for each S was computed by summing the GV of each S's LR_os and dividing that sum by the number of LR_os given by that S. This is taken as a

measure of the breadth of the generalization gradient for each S. The correlations between MGVR and number of CRs, number of LR_os and number of NoRs plus NLRs are -.07, .016, and .214. These three correlations are non-significant. These results are presented in Table 3.

4) Additional MGVRs were computed for each S on the basis of LR_os given by the S before he had given all of the responses on the PA list at least once (B-MGVR), whether to the correct SE (SE1) or not, and on the basis of the LR_os given by the S after he had given all of the list responses at least once (A-MGVR), whether to SE1 or not. The means of the B-MGVR were 35.74 and 45.88 respectively. A t-test of the difference between these means yielded $t = 4.9304$ with 38 df, $p < .005$, one-sided test. The A-MGVR was smaller than the B-MGVR for only two Ss and these reversals were very small.

Psychophysiological Data

Heart rate inter-beat interval (HRibi), heart rate in beats per minute (HRbpm), skin resistance level (SRL), and skin conductance level (SCL) were all used in the analyses exploring for relationships between the overt behavior and psychophysiological measures in this study. Frequency distributions of the HRibi and HRbpm data were computer compiled and plotted for each of the three event types (LE, TE, and BE) separately for each S and across all event types for each S. This was done to investigate the distributional properties of these measures. No evidence was found

TABLE 3

Correlations between Subjects' Correct Responses (CRs), Response Interchanges (LR_os), Non-list and No Responses (NLRs), LR_os + NLRs, Mean Generalization Value of LR_os (MGVR), and Practice List Correct Responses (PrCR).

	LR_os	NLRs	LR_os + NLRs	MGVR	PrCR
CRs	-.94**	-.63**	-1.0**	-.07	.39*
LR_os		.33	.94**	.02	-.30
NLRs			.63**	.21	-.36
LR_os + NLRs				.09	-.37
MGVR					.23

*$p < .05$, 18 df, one-sided

**$p < .005$, 18 df, one sided

indicating that HRibi was more normally distributed than HR bpm or *vice versa*. The choice between these two measures in this situation would seem to depend upon which is most powerfully and consistently related to other measures of interest. Analyses exploring possible relationships between electordermal activity and other measures included both SRL and SCL (SCL = 1/SRL). Again the preferred measure is the one which consistently yields the most powerful relationships.

All HRibi and HR bpm analyses are based on the means of these measures for the appropriate event types. The mean for HRibi for each event was computed by summing the times between each heart beat occurring during that event and dividing that sum by the number of beats summed. The mean for HRbpm for each event was computed by summing the rate (60/ibi) at which each beat within an event occurred and dividing that sum by the number of beats occurring in that event. Correlational and other analyses were computed on the basis of these HRibi and HRbpm event means.

Only one skin resistance measure was taken per event and that at the beginning of each 3 sec. event. These readings were taken in ohms or converted individually to microhmos for SRL and SCL measures respectively.

The mean HR ibi, HRbpm, SRL and SCL for test events (TEs), learning events (LEs), and blank events (BEs) were compared using analyses of variance. The scores analyzed were difference scores obtained by subtracting each *S*'s overall mean for HRibi,

HRbpm, SRL, and SCL from that S's appropriate event type mean. For example, each S's overall mean HRibi was subtracted from that S's mean HRibi for TE, LE, and BE. A simple one-way analysis of variance was performed on these obtained difference scores treating event types as treatments and subjects as replications. Duncan's New Multiple Range Test was used, where appropriate, to test for differences between specific means. Table 4 presents summaries of these analyses.

Table 4 indicates that mean HRibi and mean HRbpm are almost identical in all portions of the PA task. The SRL and SCL means arrange themselves in the order of increasing activity with increasing task demands, i.e., SRL is lowest and SCL highest when Ss are recalling and verbalizing and highest and lowest, respectively when no verbalization, learning, or recalling are required (blank events) of the Ss.

In Experiment 2, 1069 or 22.3% or the responses given were generalization responses - response interchanges (LR_os). Correlation coefficients were calculated between the generalization value (GV) of the LR_os (GVR) and the event HRibi, SRL, and SCL for each S individually. These correlations between the psychophysiological measures and GVRs were computed for: 1) those LR_os given before the S had made each list response (LR) at least once (whether to the correct SE or not); 2) after the S had given all the LRs (whether to the correct SE or not); and 3) for all the LR_os given by each S. Correlation coefficients were also calculated between

TABLE 4

Summaries of Analyses of Variance for Differences

Between Test, Learning, and Blank Events

HRibi Means less Overall Mean HRibi

Source of Variation	df	SS	MS	F
Event Type	2	.0000637	.00003185	.09468
Error	57	.0191771	.0003364	
Total	59	.0192408		

HRbpm Means less Overall Mean HRbpm

Source of Variation	df	SS	MS	F
Event Type	2	3.2287	1.61435	0.959
Error	57	95.9514	1.68335	
Total	59	99.1801		

SRL Means less Overall Mean SRL

Source of Variation	df	SS	MS	F
Event Type	2	12,204,800	6,102,400	28.6482*
Error	57	12,141,660	213,001.6	
Total	59	24,346,460		

SCL Means less Overall Mean SCL

Source of Variation	df	SS	MS	F
Event Type	2	1.9586587	0.97932935	20.80534*
Error	57	2.6830503	0.047071058	
Total	59	4.641709		

*$p < .001$

TABLE 4 (continued)

Mean Differences between TE, LE, and BE for the Psychophysiological Variables

Mean Dif.	TE	LE	BE
HRibi	0.00066	-0.000125	-0.00181 *
HRbpm	-0.223	0.2245	0.3025 *
SRL	-206.1	64.5 *	856.8
SCL	0.06465	-0.00535 *	-0.3488

*Those means not underlined with the same line are significantly different at the .005 level according to Duncan's New Multiple Range Test.

HRibi, SRL, and SCL for these same events. These correlations were, of course, based upon different numbers of responses for each S, the number of responses involved depending upon the S's performance.

These correlations are reported in terms of their number accounting for more than 10% or the variance and whether positive or negative for two reasons: 1) the different numbers of responses for each S yield different degrees of freedom for judging the statistical significance of these correlations; and 2) the strength of the relationship exhibited is just as important if not more important than the statistical significance in judging the theoretical and practical significance of relationships between peripheral psychophysiological measures and other behavioral variables. This criterion of strength demends correlations of $\pm.32$ or greater.[3] Table 5 presents a summary of these correaltional data.

The numbers in Table 5 are the frequencies with which correlations of $\pm.32$ or greater occur. The frequencies in Section A of Table 5 are based on LR_o events occurring prior to the emission of every LR, those in Section B on LR_o events occurring after the emission of every LR, and those in Section C on all events during which LR_os were emitted by the Ss.

Table 6 presents the correlation coefficients between GVR, HRibi, SRL, and SCL for all Ss pooled before all the LRs were

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[3]In the author's view, this is not a stringent requirement. An $r = \pm.32$ is significant at the .05 level, two-tailed, with 40 degrees of freedom.

TABLE 5

Frequency of Correlations Greater than ±.32 between GVR, HRibi, SRL, and SCL. Before and After All LRs Are Given and for All LR_os Pooled++

A.	GVR	HRibi	SRL	SCL	N*
GVR	--	-1 +3	-3 +4	-4 +3	20
HRibi		--	-2 +2	-2 +2	20
SRL			--	20**	20

B.	GVR	HRibi	SRL	SCL	N*
GVR	--	-2 +2	-1 +9	-9 +1	20
HRibi		--	-0 +4	-4 +0	20
SRL			--	20**	20

C.	GVR	HRibi	SRL	SCL	N*
GVR	--	-0 +1	-0 +5	-5 +0	20
HRibi		--	-3 +2	-2 +3	20
SRL			--	20**	20

*N is the number of correlations possible in each cell.

**Number of correlations between -.99 and -1.0 in that cell.

++Numbers preceded by minus (-) signs are the frequencies of negative correlations greater than -.32. Numbers preceded by plus (+) signs are the frequencies of positive correlations greater than +.32.

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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TABLE 6

Correlations Between GVR, HRibi, SRL, and SCL, for all Ss Pooled: Before and After All LRs Are Given and for All LR_os Pooled

A.	GVR	HRibi	SRL	SCL	N*
GVR	--	.01	.04	-.04	600
HRibi		--	.26***	-.16***	600
SRL			--	-.88***	600

B.	GVR	HRibi	SRL	SCL	N*
GVR	--	.04	.08	-.03	469
HRibi		--	.25***	-.08	469
SRL			--	-.88***	469

C.	GVR	HRibi	SRL	SCL	N*
GVR	--	.02	.07**	-.05	1069
HRibi		--	.25***	-.13***	1069
SRL			--	-.88***	1069

*N is the number of events and responses upon which the correlations are based.

**$p < .05$ two-sided

***$p < .01$ two-sided

Note: The significant correlations reported here are significant in the statistical sense only. The correlations between SRL and SCL follow from their being transformations of one another. The others account for too little variance to be of theoretical or practical importance within the context of this study and will not be discussed further.

given (Section A.), after all the LRs were given (Section B.), and for all LR_os pooled (Section C.).

Two more sets of correlational analyses were computed in an attempt to explore the possible relationships between GVR, HRibi, HRbpm, SRL, and SCL in smaller segments and over time within the PA task. Ss' data were analyzed by data frame, a data frame being two complete trials, that is, two successive sets of twelve LEs, a BE, twelve LEs, and a BE, respectively. For purposes of these two analyses, all TEs (response opportunities) were assigned a GV. Test events (TEs) during which the S did not respond or during which the S responded with a word not on the response list were given a GV of zero. TEs during which the CR was given were assigned a GV of 100. As before, the GVR for LR_os was the similarity rating for the appropriate SE pair.

The first per S per data frame correlational analysis excluded events with GVs less than one or greater than 99 and is based upon the same events as the correlational analysis reported in Tables 5 and 6. The second included all TEs. Table 7 presents the frequencies of correlations accounting for 10% or more of the variance. Section A of Table 7 presents the exclusive analysis of TEs (LR_os only), and Section B of Table 7 presents the inclusive analysis (all TEs). No evidence was found for reliable trends over time and Ss in the correlations summarized in Table 7.

Scatter plots were drawn of samples of all the data upon which the above correlational analyses are based. No evidence

TABLE 7

Frequency of Correlations of ±.32 or Greater in the

Per Subject Per Frame Analyses of Test Events:

A. Exclusive Analysis

	HRibi	HRbpm	SRL	SCL	N*
GVR	-26 +31	-29 +28	-42 +28	-26 +31	134
HRibi	--	-134	-11 +27	-25 +11	134
HRbpm	--	--	-26 +10	-10 +23	134
SRL	--	--	--	-130	134

B. Inclusive Analysis

	HRibi	HRbpm	SRL	SCL	N*
GVR	-5 +15	-17 +5	-6 +15	-14 +5	151
HRibi	--	-151	-15 +31	-30 +16	151
HRbpm	--	--	-27 +14	-14 +26	151
SRL	--	--	--	-151	151

*N is the number of data frames upon which the frequency counts are based. There were 200 frames in the experiment. Data frames where the variance of the GVR was zero were excluded from both of the above analyses.

was found of non-linear relationships which could have accounted for the low and inconsistent correlations.

Correlational analyses were computed in an attempt to discover relationships between Ss' task and event type mean level of HRibi, HRbpm, SRL, and SCL and the Ss' performance on six other variables:

1) S's total number of correct responses during the PA task (CRs).

2) S's total number of generalization responses during the PA task (LR_os).

3) S's total number of Non-List and No responses during the PA task (NLRs).

4) S's total number of non-CR responses (LR_os + NLRs).

5) S's mean generalization response value (MGVR).

6) S's total number of CRs on the practice task (PrCRs).

Table 3 presents the correlations between these six variables.

Tables 8 through 11 display the correlations between the six variables in Table 3 and the following five measures of HRibi, HRbpm, SRL, and SCL:

1) Mean difference of mean LE and mean TE level (LE-TE);

2) S's mean for the PA task (Total);

3) S's mean test event level (TE) for the PA task;

4) S's mean learning event level (LE) for the PA task; and

5) S's mean blank event level (BE) for the PA task.

TABLE 8

Correlations between Five Measures of HRibi and Six

Experimental Performance Measures

	LE-TE	Total	TE	LE	BE
CRs	.06	.16	.15	.16	.14
LR_os	-.12	-.24	-.23	-.24	-.21
NLRs	.19	.16	.13	.17	.16
LR_os + NLRs	-.03	-.14	-.14	-.14	-.11
MGVR	-.08	.08	.09	.06	.13
PrCRs	-.04	-.43	-.44	-.41	-.43

None of these correlations are significant at the .05 level, two-sided with 18 df.

TABLE 9

Correlations between Five Measures of HRbpm and Six

Experimental Performance Measures

	LE-TE	Total	TE	LE	BE
CRs	-.14	-.11	-.10	-.11	-.10
LR_os	.19	.20	.20	.21	.17
NLRs	-.09	-.22	-.22	-.22	-.20
LR_os + NLRs	.12	.09	.08	.09	.07
MGVR	-.02	-.07	-.07	-.07	-.10
PrCRs	.20	.40	.39	.40	.40

None of these correlations are significant at the .05 level, two-sided with 18 df.

TABLE 10

Correlations between Five Measures of SRL and Six Experimental Performance Measures

	LE-TE	Total	TE	LE	BE
CRs	.04	.47*	.47*	.47*	.47*
LR_os	.03	-.46*	-.46*	-.46*	-.46*
NLRs	-.18	-.25	-.25	-.25	-.25
LR_os + NLRs	-.04	-.47*	-.47*	-.47*	-.47*
MGVR	.19	.33	.33	.33	.34
PrCRs	-.12	-.18	-.18	-.18	-.18

*$p < .05$, two-sided with 18 df.

TABLE 11

Correlations between Five Measures of SCL and Six Experimental Performance Measures

	LE-TE	Total	TE	LE	BE
CRs	.08	-.58**	-.59**	-.58**	-.57**
LR_os	-.09	.53*	.54*	.53*	.53*
NLRs	-.01	.43	.43	.43	.42
LR_os + NLRs	-.08	.59**	.60**	.60**	.58**
MGVR	-.05	-.21	-.21	-.21	-.22
PrCR	.19	.12	.11	.12	.12

*$p < .02$, two-sided with 18 df.

**$p < .01$, two-sided with 18 df.

The correlational analyses comparing the overt behavioral data with psychophysiological data gathered in this experiment clearly indicate that only SRL and SCL are related to performance in a consistent manner in this situation.

DISCUSSION

Experiment 1 is viewed as a replication of the low-meaningful CVC trigram similarity rating study by Runquist and Joinson (1968). The findings, while not exactly the same, show no important deviations in order from the previous findings. The mean similarity ratings of CVCs sharing no common letters were somewhat higher in the present study than those found by Runquist and Joinson (1968). This may be due to the differences in the subject sample used in the two studies. For example, the Ss used in this rating study were, on the average, older than the Introductory Psychology students who provided the data for Runquist and Joinson (1968).

The major objective of Experiment 2 was to examine HR and GSR responding in relation to stimulus generalization. It is crucial that the data collected in the PA task indicate that stimulus generalization, as an empirical phenomenon, existed and was appropriately measured in this situation. The correlation between similarity and number of generalization responses ($r = .84$) provides strong evidence that stimulus element (SE) similarity is an appropriate abscissa scale for stimulus generalization in a PA task when low-meaningful CVC trigrams are used as SEs and familiar nouns as responses (LRs).

The overt behavioral data from the PA task indicate that the

major source of non-correct responses was intra-list interchange of responses: LR_os to SE1. Non-list responses (NLR) and no responses (NoRs) were given on only 4% of the response opportunities (TEs) whereas LR_os were given during 22% of the TEs. These results taken together with the high negative correlation ($r = -.94$) between the number of CRs and LR_os given by Ss indicate that the instructions were effective in eliciting a high rate of responding and that responses were quite uniformly limited to those on the response list.

The relatively low correlation ($r = .33$) between the number of LR_os and the total number of NLRs plus NoRs indicates that these two response measures are relatively independent. For this reason it seems unlikely that NLRs and NoRs should be treated as positioned at the dissimilar extreme of the similarity scale of the abscissa in a generalization study of this type.

The finding that the mean generalization value of LR_os (MGVR) decreased after the Ss had given each LR at least once conforms with results presented in Kimble (1961), Mostofsky (1965), and Honig (1966) that breadth of generalization decreases as amount of training increases. The lack of realtionships between MGVR and other performance measures is also consonant with results previously reported. Breadth of generalization has most consistently been related to strength and type of reinforcement, variables not specifically manipulated in this study (Honig, 1966; Mostofsky, 1965).

These results support the conclusion that stimulus generalization was present and appropriately measured in this experiment. Thus, analyses examining HR and GSR responding in relation to stimulus generalization are appropriate.

The series of analyses conducted to explore possible relationships between the overt behavioral data and the psychophysiological data in this experiment failed to yield consistent support for a relationship between HR and stimulus generalization. No evidence was found which can reasonably be interpreted as supporting the notion that higher HRbpm or lower HRibi occur concomitantly with larger generalization errors. This seems to conflict with the findings of Lacey (1959) and Callaway and Thompson (1953) that realtively high HR accompanies less accurate responding to exteroceptive stimuli. Differences in the experimental situations may account for these differences in results.

Callaway and Thompson (1953) obtained their evidence in a paradigm where HR was manipulated by physiological stressors. Thus, the observed deviations in both HR and perceptual responding may have been due to the physiological stressor and otherwise independent of each other.

The bulk of the evidence reported by Lacey, however, was gathered in situations where no obvious physiological stressor was applied. Those data were gathered utilizing a paradigm where no direct attempt was made to manipulate HR (Lacey, 1959;

Lacey *et al.*, 1963; and Lacey, 1967).

Docter *et al.*, (1964) failed to replicate one of Lacey's (1959) important findings as do the present data. The present experiment and that of Docter *et al.*, (1964) both employed more complex stimulus arrays than used by Lacey (1959) and were less like a simple reaction time situation. Thus, more complex stimulus processing may be required in these experiments.

Another difference between Lacey's data and that presented here is the difference in scoring of the HR data. Lacey (1959, 1963, and 1967) employed a peak-to-valley measure of HR change. This method requires longer events and greater confidence that the primary data records are artifact free than conditions of the present experiment allowed.

Evidence presented by Lazarus and his coworkers gathered in an extensive series of investigations (unfortunately confined to one rather artificial situation) indicates that the scoring method employed for HR data does affect the magnitude of correlations but, in general, does not change the direction of obtained correlations, except of course, when inverse transformations are used as between HRibi and HRbpm. The weak relationships between HR and other variables in this study might be due to the mean level scoring method employed. However, the inconsistencies in direction probably are not attributable to the HR analysis techniques. It is the lack of consistency in direction of relationships as well as their lack of strength

which leads to the conclusion that these data contain no evidence of a practically or theoretically important relationship between HR and stimulus generalization in a PA learning task.

Differences in the stimulus intake versus internal processing requirements of different event types should be reflected in the relationship between event type and psychophysiological responding (Lacey, 1967). Intuitively, it seems that committing to memory might well involve less active cognition than attempting to recall. However, the lack of relationship between HR and event type is not considered strong evidence against Lacey's (1967) theory. Obviously, learning and test events (LEs and TEs) may involve both stimulus intake and internal processing. The stimulus input from the environment is more complex in LEs than in TEs and thus the HR deceleration would be expected to be greater in the former than in the latter. However, Lacey does not specifically say whether committing to memory should involve less HR acceleration than attempting to recall. Perhaps neither of these is what Lacey means by internal processing.

The strongest evidence for HR acceleration as a concomitant of internal processing has been gathered in studies employing mental arithmetic as the experimental task. Mental arithmetic requires stimulus intake. The S must become aware of the particular problems with which he is presented. It is possible, however, that a subject acting as a desk calculator is a very

different thing from one acting as a memory bank, be he storing or retrieving.

SRL and SCL have been found to change in the direction of increased activity (SRL decrease and SCL increase) as tasks demand more activity (Lacey et al., 1963; Obrist, 1963; Campos and Johnson, 1966; and Johnson and Campos, 1967). The relationship between GSR and event types presented above may be viewed as a replication of these earlier findings. In terms of overt behavior, blank events (BEs) (high SRL and low SCL) demand the least activity from the Ss and TEs (low SRL and high SCL) demand the most.

Relationships between psychophysiological measures and task success have been reported. Hokanson and his coworkers found that males and females with resting HRbpm above 92 and 94 respectively performed better on a digit symbol substitution task than males and females with resting HRbpm less than 72 and 74 respectively. Blatt (1961) found that Ss efficient in solving a complex problem had higher HRs than less efficient problem solvers. The lack of relationship between HR and performance that was obtained in this study agrees with the results of Berry and Davis (1960) who found no relationship between HR or GSR and performance on a serial learning task. These conflicting results illustrate the important role situational factors may play in determining relationships between HR and performance.

The finding that SRL is positively and SCL negatively correlated with performance (total number of CRs, Tables 10 and 11) are not easily interpretable. GSR level could be used as a measure of arousal (Lazarus and his coworkers) or as a measure of drive in the same way that Hokanson and he coworkers used HR. One could then conclude that arousal and/or drive level was negatively related to learning performance in the present experiment. Many formulations of the relationship between performance and arousal or drive take the form of an inverted U shaped function of the general type proposed in the Yerkes-Dodson Law (Kimble, 1961). The use of such an interpretation in the present case would mean that most of the S's arousal or drive level was above optimum in the present task. This implies either arousal or drive levels were high or that the task was very difficult. These interpretations are highly speculative since no manipulations or independent measures of either arousal or drive or task difficulty are included in the study.

It should be noted that the HR and GSR data reported in this study are level measures. That is, they reflect functioning at independently specified points in the experiment. The HR data are all based upon mean HRibi or HRbpm for events while the SRL and SCL data are levels taken at the beginning of each event. The intervals upon which the HR means were based(3 sec.) were judged short enough to reflect momentary

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changes in level. Although some noise due to movement was evidenced on the polygraph records, in only 89 of the 10,400 events in the study was the HR record wholly unreadable. Thus the results are based upon a 99.15% sample of the possible event means. These data include events where artifacts precluded the reading of one or more beats and thus some event means may be slightly distorted. It is highly unlikely that these possible distortions are systematic or frequent enough to have affected the statistical significance of any of the results.

Some of the analyses included only HRibi and no HRbpm as a measure of HR. The reader is referred to Appendix A for a detailed argument supporting HRibi as the most reliable and distortion free measure of HR available in this study. HRbpm would, of course, have been included in these analyses had HRibi been consistently related to other variables.

The results of this study are viewed as providing no supporting evidence for Lacey's (1967) theory that HR acceleration is concomitant with stimulus rejection, internal processing and presumably, increased stimulus generalization while HR deceleration is concomitant with attention to environmental stimuli and presumable, accurate intake and utilization thereof. The data are consonant with Lacey's _et al._, (1963) notion of "directional fractionation" of psychophysiological functioning. HR and GSR do not relate to different aspects of the situation or performance in the same way. The results cannot, of course,

be taken as supporting evidence for specific directional fractionation hypotheses because there is no independent evidence in this study to indicate the relative positions of LEs and TEs on a bipolar stimulus-rejection versus attention-to-environment dimension. If these requirements are the same for LEs and TEs, then the results are as expected: HR is the same for LEs as for TEs. However, if LEs place a heavier emphasis upon stimulus intake and TEs on internal cognitive processing, then the results do not follow the expected pattern which would have HR lower for LEs and higher for TEs.

In summary, the present study was successful in collecting HRibi, HRbpm, SRL and SCL data concomitantly with overt behavioral data which conform well with the usual empirical defining characteristics of stimulus generalization. No consistent relationships were found between HR and GSR measures of psychophysiological responding and stimulus generalization.

Although HRibi and HRbpm were the psychophysiological variables of major interest in this study, SRL and SCL data were collected and analyzed to explore for possible patterns of psychophysiological responding in this experimental situation. Many analyses not reported here were carried out in an attempt to discover such patterns of responding without success.

A pattern of psychophysiological responding related to

overt behavioral measures might be found in this experimental situation if manipulations were employed to induce changes in the central states or processes of _S_s such as arousal or frustration manipulations. Direct manipulation of psychophysiological variables was clearly not the purpose or intent of this study.

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A P P E N D I C E S

APPENDIX A

APPENDIX A

PSYCHOPHYSIOLOGICAL VARIABLES: GSR AND HR

The abbreviation GSR will be used to refer to recordings of electrical properties of the skin. The abbreviations suggested by Venables and Martin (1967, p. 56) will be used thoughout this paper to refer to specific measures of electrical properties of the skin. SRR (skin resistance response), SRL (skin resistance level), SCR (skin conductance response), and SCL (skin conductance level) designate categories within which some of the psychophysiological data on electrical properties of the skin fall.

Conductance is the reciprocal of resistance. The two measures are usually obtained with the same apparatus and procedure. Since they may, over a wide range of instances, be distributed differently, both were used in the correlational analyses and the analyses of variance in this paper.

Level, as used above, implies the appropriate magnitude measure at predetermined points in the experiment without regard to the waveform of the record of responding.

Response, as used above, implies the frequency count or appropriate magnitude measure of specified waveforms contained in the GSR record. These waveforms are usually an increase in conductance or a decrease in resistance with a subsequent return to pre-response levels, the return being more gradual than the departure from the pre-response level.

The methodological problems confronted by investigators wishing to use GSR data have been formidable. Some controversy continues in the literature (Montagu and Coles, 1968) concerning the best way to collect GSR data and the physiological mechanisms most closely associated with the occurrence of GSR data. SRR, SRL, SCR, and SCL data collected with either bipolar or unipolar electrodes with constant current or constant voltage and AC or DC sources seem reliable and relatively free of artifacts when appropriate electrodes and electrolyte are used and when the current density and active contact area are adequately controlled (Lykken, 1959; Montagu and Coles, 1966, 1968; and Venables and Martin, 1967).

Lykken (1959) gives striking evidence supporting the contention that any report of GSR data should include adequate reference to or description of the method of measurement employed so the reader can judge the probable reliability of the data. This paper will avoid reference to GSR data whose validity is suspect as judged by the guidelines contained in Lykken (1959), Montagu and Coles (1966, 1968), and Venables and Martin (1967).

The abbreviation HR will be used to refer to data based upon the rate at which the heart beats and the intervals between beats. HRbpm refers specifically to heart beats per minute while HRibi refers to the time in seconds between heart beats. HRbpm equals sixty divided by HRibi. As with SRL and SCL,

these two measures of the same phenomenon may be distributed differently and thus may show differing strengths of relationship to other variables.

When the electrical activity associated with the beating heart is amplified and directly recorded on a primary data record, these records can easily be sorted and screened for artifacts because of the characteristic EKG waveform. If, as in the present study, a cardiotachometer is employed to record HR in a more easily digitized form, it becomes much more difficult to distinguish any artifacts in the primary data record from true HR.

Three techniques were employed to eliminate and check on possible sources of artifacts and distortions contained in HR data in this study.

1) Extensive pilot work was done to ensure that the photoelectric transducer placement provided reliable detection of heart beats and that the heart beats were reliably recorded on the polygraph record with a minimum of lost data due to S movement.

2) Polygraph records were visually checked and marked before they were digitized using an x-y recorder. The records were also checked while they were digitized on the x-y recorder.

3) Means of three second intervals (events) were used in all the analyses. This avoided gross errors which might

have occurred due to occasional premature triggering of the cardiotachometer by ensuring an accurate HRibi mean for the digitized beats in each event. This technique is not as effective in minimizing errors in HRbpm.

A method of analyzing the HR polygraph records obtained in this study which selectively used only the fastest beats or the slowest beats would maximize the influence of premature or delayed triggering of the cardiotachometer caused by movement. Therefore, such measures were deemed inappropriate for the present study.

APPENDIX B

APPENDIX B

INSTRUCTIONS

On the following pages of this booklet are listed pairs of words. The words are relatively nonsensical. Your task is to estimate the similarity between the words making up each pair. Estimates should be given according to a scale with zero representing no similarity and 100 identity. That is, if the two words in the pair are not similar at all the pair should be given a value of zero. If the two words making up the pair are identical, a rating of 100 should be assigned to it. Values in between should be used according to how close the pair is to identity.

In making your ratings start on the first page and work through the booklet by writing your rating in the blank space beside each pair. Take as much time as necessary to consider each pair carefully, but be sure and rate every pair in order.

1	2	3
PEF - YIH ____	QIH - PEF ____	XIL - YIL ____
NIY - WUX ____	NIY - QIH ____	WUX - NIY ____
QIH - MUB ____	MUB - VAW ____	WUX - FAJ ____
QOH - XIY ____	XIL - NIY ____	YIL - FAJ ____
FAJ - XIY ____	XIL - WUX ____	FAJ - QOH ____
MUB - WUX ____	XIL - QIH ____	YIL - MUB ____
WUX - XIY ____	MUB - PEF ____	WUX - VAW ____
PEF - MUB ____	QOH - YIH ____	NIY - XIL ____
QIH - FAJ ____	FAJ - WUX ____	QOH - NIY ____
FAJ - NIY ____	XIL - XIY ____	YIH - MUB ____
YIH - VAW ____	QIH - VAW ____	QIH - YIL ____
MUB - YIH ____	PEF - NIY ____	VAW - NIY ____

4	5	6
QOH - XIL ____	NIY - VAW ____	PEF - WUX ____
YIL - NIY ____	QOH - MUB ____	XIY - QOH ____
XIY - XIL ____	WUX - XIL ____	XIY - NIY ____
NIY - MUB ____	VAW - PEF ____	WUX - PEF ____
YIL - WUX ____	YIL - XIY ____	PEF - QIH ____
PEF - QOH ____	YIL - PEF ____	VAW - QIH ____
XIL - FAJ ____	MUB - NIY ____	NIY - YIL ____
YIL - YIH ____	VAW - XIY ____	FAJ - MUB ____
XIL - WUX ____	XIY - MUB ____	QIH - XIL ____
WUX - YIL ____	WUX - MUB ____	FAJ - YIH ____
MUB - QIH ____	YIH - QOH ____	QOH - PEF ____
VAW - QOH ____	YIH - QIH ____	WUX - YIH ____

[illegible]	[illegible]	[illegible]
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7

PEF - XIL ____

XIY - VAW ____

FAJ - PEF ____

XIY - PEF ____

FAJ - YIL ____

NIY - PEF ____

XIL - QIH ____

VAW - WUX ____

QOH - VAW ____

YIH - WUX ____

YIH - NIY ____

QOH - WUX ____

8

FAJ - QIH ____

PEF - VAW ____

NIY - QOH ____

XIY - FAJ ____

VAW - FAJ ____

VAW - MUB ____

MUB - XIL ____

MUB - XIY ____

VAW - XIL ____

NIY - FAJ ____

MUB - YIL ____

QOH - FAJ ____

9

XIL - MUB ____

YIL - VAW ____

QIH - NIY ____

XIY - YIH ____

YIH - FAJ ____

QIH - XIY ____

MUB - FAJ ____

YIH - PEF ____

FAJ - VAW ____

NIY - YIH ____

VAW - YIH ____

XIL - QOH ____

10

XIL - VAW ____

YIH - YIL ____

PEF - XIY ____

VAW - YIL ____

MUB - QOH ____

WUX - QIH ____

QIH - QOH ____

YIH - XIL ____

PEF - FAJ ____

XIY - YIL ____

WUX - QOH ____

XIY - QIH ____

11

QOH - QIH ____

QIH - WUX ____

YIL - QOH ____

YIH - XIY ____

QOH - YIL ____

QIH - YIH ____

XIL - PEF ____

PEF - YIL ____

YIL - XIL ____

XIL - YIH ____

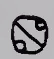
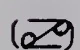
NIY - XIY ____

FAJ - XIL ____

APPENDIX C

APPENDIX C

PRACTICE LIST

First Order and Third Order		Second Order	Fourth Order
	3	5	9
	1	1	2
	9	7	3
	7	8	4
	2	4	5
	5	9	1
	4	2	7
	8	3	8

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[illegible]

[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX D

APPENDIX D

PAIRED ASSOCIATES LEARNING MATERIAL

First Order	Second Order	Third Order	Fourth Order
XIY DOG	NIY LIP	VAW JOB	YIL TOP
VAW JOB	YIH CAR	QIH RED	MUB HAT
YIH CAR	PEF ICE	YIL TOP	NIY LIP
QOH SUN	XIL AIR	WUX EGG	YIH CAR
YIL TOP	FAJ BIT	FAJ BIT	XIY DOG
FAJ BIT	WUX EGG	XIL AIR	FAJ BIT
XIL AIR	QIH RED	XIY DOG	PEF ICE
NIY LIP	MUB HAT	YIH CAR	XIL AIR
MUB HAT	QOH SUN	QOH SUN	WUX EGG
PEF ICE	XIY DOG	NIY LIP	QIH RED
QIH RED	YIL TOP	MUB HAT	QOH SUN
WUX EGG	VAW JOB	PEF ICE	VAW JOB

YIH	WUX	MUB	QOH
PEF	YIH	XIL	MUB
NIY	NIY	XIY	QIH
VAW	FAJ	NIY	YIH
XIY	XIY	QIH	YIL
FAJ	QOH	PEF	NIY
XIL	MUB	WUX	WUX
WUX	PEF	YIL	XIL
QIH	XIL	FAJ	FAJ
QOH	QIH	QOH	XIY
YIL	VAW	VAW	PEF
MUB	YIL	YIH	VAW

[illegible]

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[illegible]		[illegible]		[illegible]		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX E

APPENDIX E

PAIRED ASSOCIATES TASK INSTRUCTIONS

"I would like you to complete what psychologists refer to as a paired associates task now. This task will require your full cooperation and concentration. It is extremely important that you pay very close attention to the instructions that I give you and that you follow them exactly.

Please look at the little screen on the table in front of you. In the first paired associates task, a symmetrical geometric figure will be paired with an arabic numeral, that is a number from 1 to 9. Each geometric figure is paired with one number. All of the number-figure pairs will be visible on the screen one at a time for a short period of time. As a pair appears on the screen, say the number and try to remember which geometric figure it is paired with.

After all the pairs have appeared on the screen, the screen will be blank for a short period of time. Then, the geometric figures will appear on the screen alone. When a geometric figure appears on the screen, say the number with which it was paired. If you cannot remember which number the figure goes with, say any number from one to nine. In other words, say a number every time a geometric figure appears on the screen. I want you to guess if you do not remember the right number. It is very important that you say a number each time a geometric figure appears on the screen.

Now please tell me what you are going to do so I can be sure that you understand the instructions." (Any part of the instructions which the S indicated he did not understand were repeated.)

"Now, we will begin. Remember, first the geometric figure-number pairs will be presented. Say the number as each pair appears. Next, the geometric figures will appear by themselves. Say a number as each of the figures appears. Guess if you are not sure of the correct number. This is a fairly complex task and everyone makes mistakes on it. You must guess so that we can know the type of mistakes you make."

(The projector was started and the responses recorded. The S was prompted to guess if necessary. The practice list was run for six trials.)

"Very good! You have done quite well on this task. Now, I would like you to do another task which is exactly the same except that instead of symmetrical geometric figures paired with numbers, combinations of three letters will be paired with names of things, that is nouns. This task will be longer and more difficult than the last task but I am sure you will do all right." (The film strips were changed while the above instructions were given.)

"Now, there will appear on the left of the screen, three letter combinations which are not words. On the right of the screen, paired with these three letter combinations will be

words with which you are familiar and which are the names of things. The procedure for this task will be the same as for the last paired associates task.

As the three letter combination and word pair appear on the screen, say the word and try to remember the pair. After all the pairs have appeared on the screen, there will be a short pause and then the three letter combinations will appear. When a three letter combination appears alone, say the word which you think was paired with it. For the first few times, you will probably not remember for sure which word goes with which three letter combination; so guess. That is, say any word that comes to mind, even a word which is not on the list. It is extremely important that you say a word each time a three letter combination appears so if you cannot remember the correct word as soon as the three letter combination appears, guess. The pairs and the three letter combinations appear on the screen for only a very short period of time so guess if you are not sure of the correct word as soon as the three letter combination appears. Now please tell me what you are going to do so I can be sure that you understand the instructions."

(If necessary the instructions were repeated in whole or in part.)

"You may learn all the pairs before the task is over. If you do so, just keep following the instructions until I tell

you to stop."

(The projector was started and the S was reminded to guess if necessary.)

APPENDIX F

APPENDIX F

PAIRED ASSOCIATES TASK DATA SHEET

Date____________
Name____________

YIH CAR						WUX EGG					
PEF ICE						YIH CAR					
NIY LIP						NIY LIP					
VAW JOB						FAJ BIT					
XIY DOG						XIY DOG					
FAJ BIT						QOH SUN					
XIL AIR						MUB HAT					
WUX EGG						PEF ICE					
QIH RED						XIL AIR					
QOH SUN						QIH RED					
YIL TOP						VAW JOB					
Sum CRs											

MUB HAT						QOH SUN					
XIL AIR						MUB HAT					
XIY DOG						QIH RED					
NIY LIP						YIH CAR					
QIH RED						YIL TOP					
PEF ICE						NIY LIP					
WUX EGG						WUX EGG					
YIL TOP						XIL AIR					
FAJ BIT						FAJ BIT					
QOH SUN						XIY DOG					
VAW JOB						PEF ICE					
YIH CAR						VAW JOB					
Sum CRs											

[illegible]

APPENDIX G

APPENDIX G

A PRIORI METHODOLOGICAL CONSIDERATIONS

Experiment 2 was designed to meet thirteen conditions which were deemed important to the accurate determination of the relationship, if any, which exists between HR, GSR, stimulus generalization, and other performance measures in a PA task.

1. The mean similarities between different stimulus element (SE) pairs must be of sufficient range to allow measurement of the relationship which might exist between SE similarity and stimulus confusion or response interchanges among stimuli which occur during the performance of the PA task and constitute the evidence for stimulus generalization.

2. The stimulus and response material should be selected and assembled into pairs avoiding mnemonic and formal similarity links between SEs and response elements, the influence of which would be confounded with generalization.

3. Responses should be highly familiar to the *Ss* since stimulus-response pairing and not response acquisition is of primary interest.

4. Responses should be dissimilar and easily distinguishable, both in terms of formal similarity and meaning since stimulus and not response similarity is the abscissa scale and hence, the primary independent variable on the PA material.

5. Learning and testing events (LEs and TEs) should be reasonably short to ensure that the list is not learned too

quickly. If the PA task were performed too well, too few errors would be committed to reflect possibly reliable relationships between SE similarity and response interchanges.

6. Instructions should not be stress producing but should place their emphasis upon response elicitation. The instructions should encourage the free responding necessary for generalization data and discourage anxiety about response errors. The psychophysiological effects of extreme anxiety about response errors might obscure any relationship between HR and stimulus generalization.

7. An attempt should be made to minimize or counterbalance the kind of verbalization effects reported by Campos and Johnson (1966) and Johnson and Campos (1967). Instructing the Ss to verbalize the response elements during both learning events (LEs) and testing events (TEs) is a plausible means of controlling for the effects verbalization alone might have upon HR in different phases of the PA task.

8. A practice task having the same format as the experimental task should be employed to familiarize the Ss with what is expected of them and to establish a responding set; i.e., increase the likelihood that the S will have some recordable response during each TE.

9. Learning and testing phases of the task should be separated to avoid confounding the possible relationships between task performance and the psychophysiological measures

due to recovery cycles or compensatory cycles of psychophysiological increase or decrease attributable to rapidly changing behavioral requirements (Graham and Clifton, 1966).

10. The psychophysiological baseline data should be gathered from relatively neutral periods within the task thereby avoiding non-specific or general effects which the task and experimental situation might have upon the psychophysiological measures. These effects should be prevented from entering into comparisons between the baseline, the learning, and the testing psychophysiological levels. This follows from the interest here in determining whether different psychophysiological indices are relatively higher or lower in one part of the task than in other parts and concomitantly with particular types of responses. The interest here is not in determining the level of psychophysiological indices in a PA task or parts thereof relative to some other task or situation.

11. The procedures and techniques used to collect the psychophysiological data must be relatively unobtrusive and unrestrictive in the behavioral situation. This is to ensure that the collection of psychophysiological data does not alter the performance of the Ss, rendering that performance different from a performance in the same situation without psychophysiological data recording.

12. The techniques and apparatus employed in the collection of the psychophysiological data must be accurate and reliable. Lykken (1959), Montagu and Coles (1966), and Venables and Martin (1967) provide detailed reviews of the technical considerations involved in the collection of the psychophysiological measures taken in this study.

13. The techniques and apparatus employed in the collection of the psychophysiological data must be such that the data are <u>not</u> rendered unreliable or obscured for major or systematic portions of the task situation due to <u>S</u> movement or artifacts produced by the experimental apparatus.

G L O S S A R Y

GLOSSARY

A-MGVR - mean generalization value of responses emitted after all the list responses were emitted at least once

BE - blank event, BEs separated testing and learning phases of the PA task, every thirteenth event, 3 sec. duration

B-MGVR - mean generalization value or responses emitted after all the list responses were emitted at least once

CR - correct response

CVC - consonant-vowel-consonant

E - experimenter

GSR - galvanic skin response, the general class of electrodermal measures of which SCL and SRL are used in this study

GV - generalization value

GVR - generalization value of a response

HR - heart rate

HRbpm - heart rate in terms of beats per minute

HRibi - heart rate in terms of inter-beat interval

LE - learning event, the presentation of one stimulus-response pair of the PA list, 3 sec. duration

LR - list response, a response on the PA list

LR_o - list response other, a generalization response

MGVR - mean generalization value of responses

NLR - non-list response, a response not on the PA list

NoR - no response

PA - paired associates

PrCR - practice list correct response(s)

RT - reaction time

<u>S</u> - subject

SCL - skin conductance level

SE - stimulus element, stimulus member of a PA pair

SE1 - critical or currently presented SE

SEo - SE other than the critical or currently presented SE

SRL - skin resistance level

TE - test event, SE presentation, response opportunity, 3 sec. duration